PERFORMANCE-OPTIMAL AND UNCERTAINTY-ROBUST ANALYSES OF THE LITTLE BOY WEAPON (U)

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Abstract

In April 1943, the wartime project-Y, also known as the "Manhattan project," was tasked with the development of a new type of weapon based on the principle of nuclear fission. Physicists and engineers were gathered in Los Alamos, New Mexico, and provided with a series of five lectures detailing everything that was known at the time about the possibility of developing a practical military weapon using a fast neutron chain reaction. The lectures were assembled in a document known as the Los Alamos Primer, and subsequently declassified by the U.S. Government in 1965.[2]

When the project-Y was initiated, many physical properties of the nuclear materials were uncertain. Likewise, knowledge about some of the physical processes involved in nuclear fission was to great extent unknown. To alleviate the lack-of-knowledge, conservative assumptions were made. It is often suggested that empirical performance optimization practices made possible the successful completion of the project. Even though the advent of computational resources and numerical methods have changed much of the scientific landscape, contemporary approaches to design in physics and engineering still rely on practices such as calibration, performance optimization, and study of the reliability.

This paper surveys the sources of uncertainty reported in the Los Alamos Primer and other pre-1943 documentation. Using the "Little Boy" weapon as an example for calculations, it is argued that this design is not performance-optimal, as commonly thought. Instead, it offers some degree of robustness to uncertainty and lack-of-knowledge, while "*satisficing*" performance—that is, making it just "good enough." This conclusion is reached by performing a formal analysis of the trade-off between performance and robustness-to-uncertainty. Because many of the sources of uncertainty identified do not accommodate a probabilistic description, the analysis is carried out through the theory of information-gap, which combines probabilities to convex models of uncertainty.[3]

Implications for modern decision-making such as the accreditation of numerical simulations (also referred to as model verification and validation) and the certification of engineered systems are two-fold. First, conservatism could be avoided to a great extent, if more emphasis were placed on exploring the trade-off between performance-requirement and robustness-to-uncertainty. Second, decision-making frameworks exist that do not, unlike probabilistic-based reliability methods, artificially restrict the representation of uncertainty or lack-of-knowledge to a strict probabilistic one.

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[2] Serber, R., **The Los Alamos Primer, The First Lectures on How to Build an Atomic Bomb**, University of California Press, Berkeley, California, 1992.
[3] Ben-Haim, Y., **Information-Gap Decision Theory: Decisions Under Severe Uncertainty**, Academic Press, 2001.